Original Article

Construction and validation of logMAR visual acuity charts in seven Indian languages

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Purpose: The evaluation of visual impairment requires the measurement of visual acuity with a validated and standard logMAR visual acuity chart. We aimed to construct and validate new logMAR visual acuity chart in Indian languages (Hindi, Bengali, Telugu, Urdu, Kannada, Malayalam, and Assamese). **Methods:** The commonly used font in each language was chosen as the reference and designed to fit the 5 × 5 grid (Adobe Photoshop). Ten letters (easiest to difficult) around median legibility score calculated for each language based on the results of legibility experiment and differing by 10% were selected. The chart was constructed based on the standard recommendations. The repeatability of charts was tested and also compared with a standard English Early Treatment Diabetic Retinopathy Study (ETDRS) logMAR chart for validation. **Results:** A total of 14 rows (1.0 to -0.3 logMAR) with five letters in each line were designed with the range of row legibility between 4.7 and 5.3 for all the language charts. Each chart showed good repeatability, and a maximum difference of four letters was noted. The median difference in visual acuity was 0.16 logMAR for Urdu and Assamese chart compared to ETDRS English chart. Hindi and Malayalam chart had a median difference of 0.12 logMAR. When compared to the English chart a median difference of 0.14 logMAR was noted in Telugu, Kannada, and Bengali chart. **Conclusion:** The newly developed Indian language visual acuity charts are designed based on the standard recommendations and will help to assess visual impairment in people of these languages across the country.

Key words: Legibility, logMAR charts, standardized visual acuity chart, validation, visual acuity, visual impairment

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Visual acuity is the measurement of the ability to resolve spatial objects. Testing visual acuity is the first step in the management and treatment of visual problems. There are different types of vision testing charts available to measure visual acuity, and the most commonly used chart is Snellen chart.[1] The Snellen design is available in a variety of targets and also in different regional languages. Snellen charts have the drawback for not meeting the visual acuity measurement standards.[2,3] Bailey–Lovie logMAR visual acuity charts are preferred to Snellen charts for testing visual acuity as they follow the standard recommendations for measuring visual acuity and optotypes used are adapted by the British Standards Institutions.[4]

India has many languages, of which 21 languages are officially registered and used as the mode of communication in different parts of the country.[5] Based on the Census 2011 report, we selected the most widely used 12 languages. Hindi is the national language and predominantly spoken by almost 41% of the population of India. Languages like Bengali (8.11%), Telugu (7.19%), Tamil (5.91%), Urdu (5.01%), Kannada (3.69%), Malayalam (3.21%), and Assamese (1.28%) also spoken and taught as the first language in regional schools (Census of India, 2011). There are visual acuity charts available in Hindi, but these are not made in conformity with the International recommendations as given by the Committee of Vision and the World Health Organization.[3]

The prevalence of visual impairment is increasing around the world and India is one of the countries with the highest rates of visual impairment. To help assess the visual impairment accurately and enable comparison in people speaking different languages, we aimed to construct and validate standard logMAR visual acuity charts based on the National Academy of Sciences–National Research Council recommendations in different Indian vernacular languages.[3]

Methods

The construction and validation of logMAR visual acuity charts in seven Indian languages, chosen from the top 12 commonly spoken languages in the country are explained.[5] The study was

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conducted in accordance with the tenets of the Declaration of Helsinki and was approved by the Institutional Review Board.

The languages chosen were Hindi, Bengali, Telugu, Urdu, Kannada, Malayalam, and Assamese. The construction of logMAR visual acuity chart includes the style and selection of fonts, font designing, and legibility.

Style and selection of fonts

The legibility of letters varies from one font style to another for a same letter. We chose the most commonly used font in newspapers, magazines, school books, etc., in each language [Table 1]. All the letters in a language cannot be chosen for the construction of a chart. We excluded letters that had multiple curved contours, within letter crowding, similar sounding/pronunciation, and similar letters.

Font designing

All the letters selected were enhanced to 100% contrast using image processing software (Adobe Photoshop v7.0, Adobe Systems, Inc., San Joe, CA, USA) and the individual letters were stored as bitmap files. The letters were redesigned to fit a 5 × 5 grid. The width of the letter was adjusted and fitted into the grid as shown in Fig. 1. The letters selected for inclusion in the chart construction were verified by the linguist.

The sample size was calculated considering unpaired groups with an alpha error of 0.05, the power of 80% with an acceptable mean difference of 0.05 logMAR (half-line)[6] and standard deviation of 0.07. The estimated sample size was 32. For every script, we recruited participants who had studied the language at least till high school level. Multilingual participants were included for more than one language visual acuity chart measurement. They were tested for their ability to identify the letters in the given language. Those who could correctly identify the letters and had best-corrected visual acuity better than or equal to 6/6, normal contrast sensitivity function with Functional Acuity Contrast Test, refractive error within ± 3.00 DSph or − 1.50 Dcyl, and no other ocular abnormalities or with no history of previous ocular surgeries were enrolled for the experiment. Written informed consent was obtained from all the participants who were willing to participate in the study.

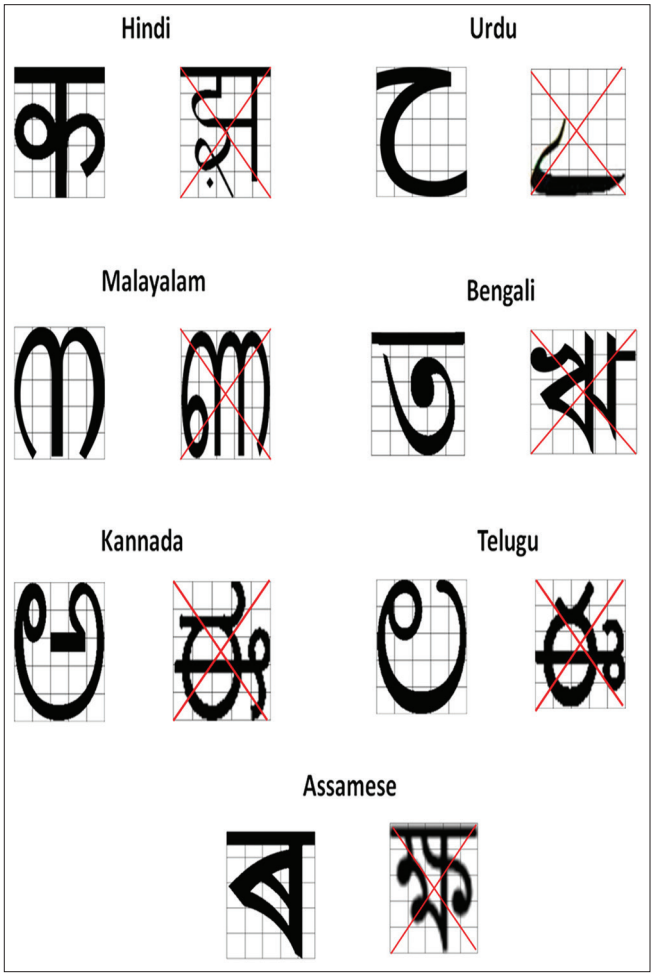

Figure 1: Font designing

Table 1: Font style, row legibility, and repeatability

Language	Legibility				Validation				
	Font name	Number of optotypes selected	Age (years), mean±SD	Row legibility (range)	Sample size	Age (years), mean±SD	Median difference (IQR)		
							Between ETDRS English and language: Time 1*	Between ETDRS English and language: Time 2†	Between language: Time 1* and Time 2†
Hindi	Devanagri	19	32.0 (13.3)	4.8-5.2	91	29.6 (10.2)	0.10 (0.08-0.18)	0.12 (0.10-0.18)	0.00 (0.00-0.04)
Telugu	Eenadu	18	30.5 (10.3)	4.8-5.2	29	31.0 (8.2)	0.16 (0.12-0.18)	0.14 (0.10-0.16)	0.02 (0.00-0.04)
Urdu	Dejavu sans	15	35.0 (7.2)	4.7-5.3	28	30.1 (7.5)	0.15 (0.13-0.17)	0.16 (0.13-0.18)	0.02 (0.02-0.04)
Kannada	Baraha	24	31 (9.3)	4.9-5.0	27	33.8 (6.1)	0.16 (0.12-0.18)	0.14 (0.10-0.20)	0.04 (0.02-0.04)
Malayalam	Manorama	16	32.2 (10.2)	4.9-5.1	39	30.5 (7.2)	0.10 (0.10-0.14)	0.12 (0.10-0.14)	0.02 (0.00-0.04)
Assamese	Ramdhenu	25	34.5 (8.2)	4.9-5.1	92	31.1 (8.8)	0.16 (0.12-0.20)		
Bengali	Kaal purush	24	32.2 (11.2)	4.9-5.1	31	28.5 (10.3)	0.14 (0.12-0.18)		

*Time 1 represents the first measurement, †Time 2 represents the repeated measurement, after a gap of 30-60 min from the Time 1. SD: Standard deviation, ETDRS: Early Treatment Diabetic Retinopathy Study, IQR: Interquartile range

Legibility measurement

The relative legibility was determined using methods described by Strong and Woo by requiring the participants to recognize letters presented on a computer monitor.[7] The experimental setup used for measuring legibility included a cathode ray tube monitor where each letter was randomly presented at the center of a white background using a program written in Matlab 7.2 (R2006a) (The Mathworkds, Inc., Natick, MA, USA).[6] All the participants were seated at a fixed distance of 1.5 m from the monitor. One eye was used for the experiment and was chosen based on the toss of a coin. A +1.50 DSph lens was placed in front of the viewing eye and the other eye was occluded. Plus lenses were used to compensate for distance by creating blur. A point image of the letter was presented on the monitor and the participant was instructed to increase the letter size until it was recognized. The measurement of the threshold for the identification of each letter was repeated thrice. An average time of 50:00 min per participant was taken to complete the legibility experiment. The legibility of a given letter is defined as the ratio of the average visual angle subtended by each letter for all the participants to the average visual angle subtended by all the letters for all the participants. The same method was used for evaluating the relative legibility for all the languages. Ten letters around the median legibility score and differing at most by 10% were selected.

Chart construction

The standards of visual acuity include[3] that the progression of letters size on a chart should be equivalent to 1.256 or 0.1 log unit (geometric progression). Ten 5 × 5 letters were used with almost equal legibility. Each row had the same number of letters (5 per line). The spacing between letters was equal to one letter width. The space between rows was equivalent to the height of the letters in the smaller row. Externally illuminated visual acuity charts were constructed for all the 7 languages of size 65 cm (Vertical) × 63 cm (Horizontal). The illuminance on VA charts was maintained between 400 and 600 lux. The chart was designed for a standard viewing distance of 4 M. The visual acuity range measurable from this standard distance was 6/60 to 6/3 (1.0 to − 0.3 logMAR), with 14 rows of letters. The construction of visual acuity chart adopted the recommendations by the committee on vision.[3]

Validation of chart

Participants recruited for validation had the same criteria as those recruited for legibility. The visual acuity was tested with one eye at 4 m from the chart and the nontested eye was occluded. Visual acuity was tested using both Early Treatment Diabetic Retinopathy Study (ETDRS) chart (Good-Lite, Elgin, IL, USA) and the newly developed logMAR chart. The testing eye and the chart to be tested first was chosen randomly by a toss of a coin. The participant was instructed to read from the top left until the end of the chart. The correctly read letter was assigned a score of 0.02 for both ETDRS and newly designed logMAR chart. The repeatability of the chart was tested using the same procedure with a gap of 30–60 min in between by the single examiner.

Statistical analysis

Statistical analysis was performed using SPSS version 17 (SPSS Inc., Chicago). Test for normality and appropriate statistical tests (Mann–Whitney and Wilcoxon) were performed for visual acuity measured with ETDRS chart and newly constructed language charts.

Results

Construction of chart

The font style was chosen in each language and the image of newly designed fonts in each of the seven languages is shown in Tables 1 and 2. The range in row legibility for each language chart is presented in Table 1. The legibility scores of the 10 letters (most difficult to easiest) are presented in Table 2.

Validation

The median difference in the visual acuity level between the ETDRS English chart and the newly developed seven languages chart is presented in Table 2 ($P < 0.001$). The repeatability of each visual acuity chart was tested within a gap of 30–60 min and the median difference for each language is presented in Table 1. The median difference in repeatability of the visual acuity measure (time 1 and 2) was 0.00 logMAR for Hindi chart ($P = 0.015$), 0.02 logMAR for Telugu ($P < 0.01$), 0.02 logMAR for Urdu ($P = 0.091$), 0.04 logMAR for Kannada ($P = 0.023$), and 0.02 logMAR for Malayalam chart ($P = 0.770$). The repeatability for each chart was not clinically significant, and a maximum difference of four letters was noted [Table 1]. The median difference in the visual acuity between ETDRS English chart for each language is plotted in Fig. 2. The response from the second measurement was considered. The median difference in visual acuity measured during the second time between language and ETDRS English chart was found to be significantly higher (0.16 logMAR) in Urdu and Assamese logMAR chart ($P < 0.001$). The median difference was lower (0.12 logMAR) for Hindi and Malayalam logMAR visual acuity chart ($P < 0.001$). Telugu, Kannada, and Bengali logMAR chart had a median difference of 0.14 logMAR compared to the English chart ($P < 0.001$). The difference between English and language chart in 25th and 75th quartile was 0.10 and 0.20 logMAR, respectively.

Discussion

The logMAR visual acuity charts are used as the gold standard for clinical research due to the chart construction and design advantage over the traditional Snellen chart.[8] The newly

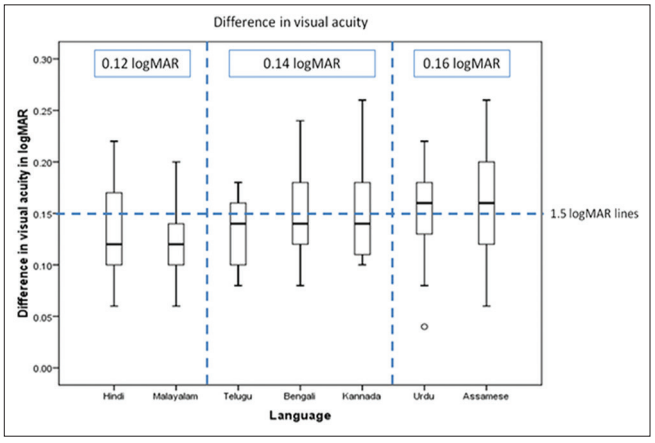

Figure 2: The median difference in the visual acuity between Early Treatment Diabetic Retinopathy Study English chart for each language

Table 2: The legibility scores of the selected ten letters for seven languages

	Hindi		Bengali		Telugu		Urdu		Kannada		Malayalam		Assamese	
	Font	LS	Font	LS	Font	LS	Font	LS	Font	LS	Font	LS	Font	LS
Difficult letter	अ	0.94	ত	0.94	ఆ	0.90	ع	0.84	ಧ	0.96	ഒ	0.96	জ	0.97
	ठ	0.95	ঞ	0.95	ఽ	0.91	ن	0.84	ಢ	0.96	ഘ	0.96	ৰ	0.97
	द	0.97	ক	0.97	ఘ	0.97	گ	0.86	ಐ	0.96	ട	0.96	ত	0.97
	ध	1.00	ধ	0.98	ద	0.99	ت	0.96	ಸ	1.00	ങ	1.00	স	0.97
	ब	1.02	য	1.00	ఒ	1.00	ر	1.00	ಅ	1.00	ര	1.00	অ	0.99
	त	1.02	ম	1.01	ట	1.00	ب	1.05	ಳ	1.00	ല	1.00	ও	1.00
	स	1.02	ভ	1.02	ఐ	1.01	ص	1.06	ಬ	1.00	ന	1.00	ভ	1.02
	म	1.03	ল	1.03	ల	1.05	ق	1.12	ಎ	1.02	ഇ	1.02	ন	1.03
	ष	1.07	খ	1.03	ఠ	1.06	ټ	1.12	ಫ	1.04	പ	1.04	ফ	1.03
Easiest letter	ग	1.07	স	1.08	ఘ	1.07	ث	1.12	ಟ	1.07	ഖ	1.07	ঘ	1.03

LS: Legibility score

constructed Hindi, Telugu, Urdu, Kannada, Malayalam, Bengali, and Assamese visual acuity charts met the prescribed standards of the logMAR chart shown in Fig. 3 in a minified form.

The physical legibility of letters appears to be a function of letter style and the critical detail that can be resolved.[9] This could be the primary factor causing the difference in visual acuity measured between English and Indian languages in the newly designed visual acuity charts. However, the difference was between one and approximately one-half logMAR lines. The minimal stroke width in Urdu, Bengali, and Assamese decrease the critical detail in a letter leading to difficulty in recognizing the font as compared to fonts in English. The width and critical detail in Malayalam and Hindi language were noted to have better legibility compared to other languages. This difference was one-half logMAR lines for Telugu and Kannada. The choice of font style can have an effect on this difference. It has been reported that English font type (Georgia, Times New Roman, Plantin, Verdana, Arial, and Franklin) had a significant effect on legibility.[10] To minimize the effect of font type, we have selected commonly used and familiar fonts in each language from newspapers, magazines, and school textbooks.

The other important factor to be considered in visual acuity chart construction is equal row legibility. Fewer letters chosen through legibility experiment can lead to memorization of alphabets resulting in overestimating the visual acuity measure. In chart construction, by selecting a larger number of letters (>10), we need to balance selection for equal legibility in each line of the chart. With more number of letters in a line (>5), error analysis needs to be evaluated. If a person wrongly reads the first letter on the line, the probability that this letter, when repeated in the same row, would be misread as another letter is high. This necessitates the calculation of row legibility and each line in the chart should have almost equal legibility. The other reason for this calculation is the effect of randomly selecting easy to a difficult letter.

The comparison of recognition acuity (identifying alphabets/letter optotypes) and resolution acuity (detecting a gap in Landolt C) in normal individuals showed a small difference which is likely to be clinically insignificant. However, a significant difference in visual acuity was noted in conditions such as macular hole and maculopathy with resolution acuity worse than recognition acuity.[11,12] Letters used as visual acuity test targets have a major disadvantage because all letters do not have equal legibility. Unlike English, Indian languages commonly have curves which cause within letter crowding and makes them less legible as the visual angle decreases. This factor was considered for selection of letters. In addition, letters which share similar phonetics, appearance, and difficult to fit (with ascenders and descenders) into a 5 × 5 grid were excluded. For the validation of the newly developed visual acuity chart, we excluded eye diseases and eyes with media opacities so as to avoid the confounding effects of age-related changes in ocular media which could affect the visual acuity. This resulted in a younger cohort being recruited. In older adults without significant changes in contrast related to age or media opacities, we believe it would not affect visual acuity testing. In the Hindi visual acuity chart developed by Khamar *et al*., letters were selected based on their difficulty score and were divided as easier, moderate, and difficult.[13] However, the criterion for selection was not clear. In the current study, letters were selected based on near equal legibility deviating not more than 10% from the average value.[7,14] The difference

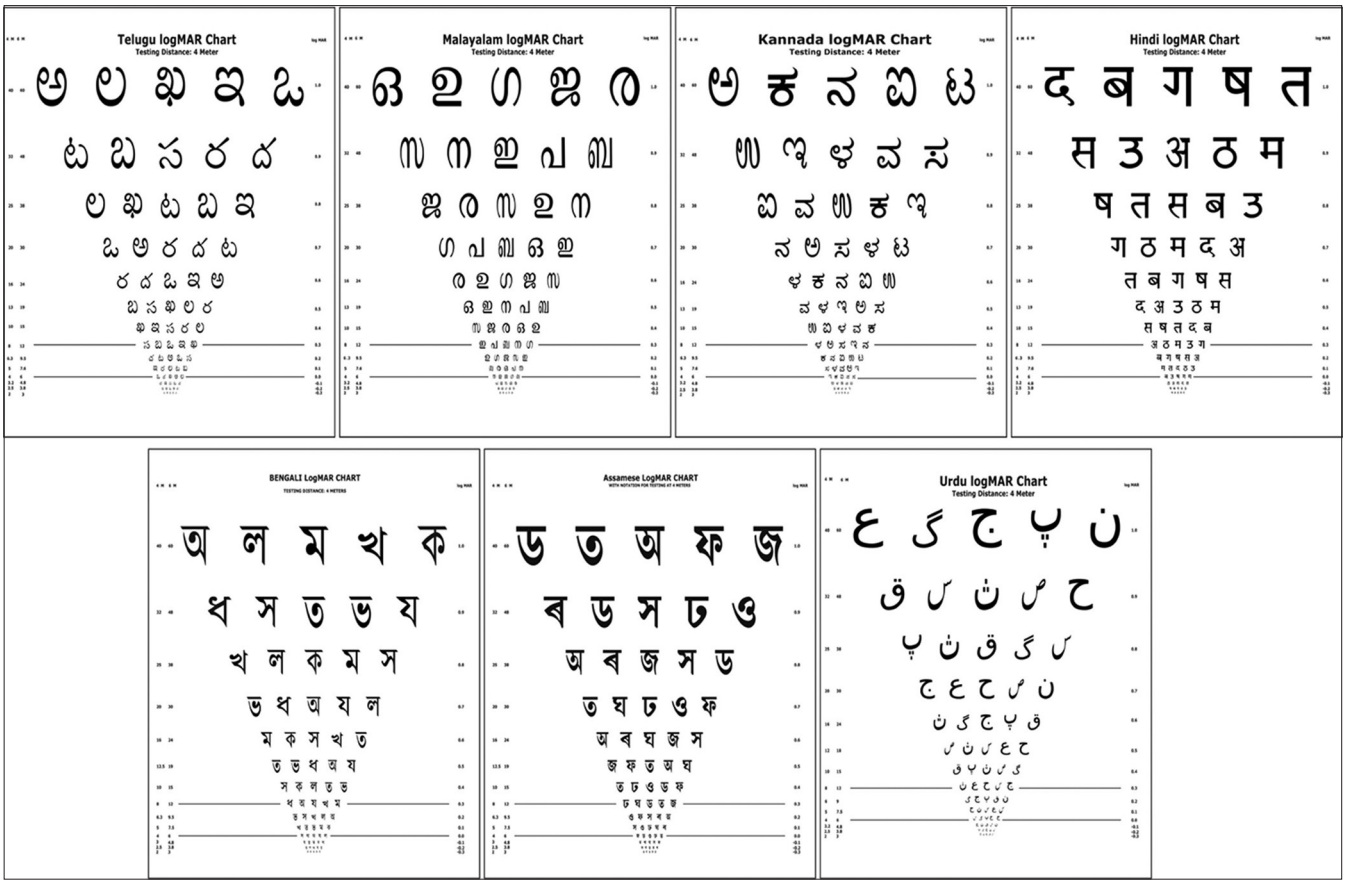

Figure 3: The minified version of the newly constructed logMAR visual acuity charts

in legibility scores between the letters selected in the newly designed Hindi chart as compared to the chart designed by Khamar *et al*.[13] could be due to the font style. The width of the letter was designed to fit the grid and avoid within letter crowding in the newly designed chart.

There is a difference of opinion for the acceptable repeatability of logMAR visual acuity chart. The range reported in literature varied between 0.2 logMAR (two line) [15] and 0.15 logMAR (7.5 letters).[16,17] The present study showed a range of no difference to two letters difference for repeatability in each language. The average difference in visual acuity measure in each of Indian language charts as compared to the ETDRS English visual acuity chart ranged between 6 letters and 8 letters (approximately one logMAR line). This is unlikely to make a significant difference if the same language chart is used pre- and posttreatment. However, to evaluate the level of vision of an individual, the difference due to the use of language chart has to be considered. The chart with which visual acuity is evaluated has to be documented. The standards of visual acuity chart recommend 10 optotypes approximately with equal legibility, logarithmic separation of 0.1 unit between the lines and luminance on the white background of 85 ± 5 Cd/m^2.[3]

Conclusion

The newly developed visual acuity charts are designed based on the recommended standards and can be used in the respective language states across the country. However, the difference in visual acuity measured as compared to English or Illiterate charts need to be considered if the charts are alternatively used.

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Conflicts of interest

There are no conflicts of interest.

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